Spring 5-8-2024

Revitalizing Turtle Creek Park

Michael Hardyway
Bucknell University, mkh017@bucknell.edu

Ethan Harm
Bucknell University, edh013@bucknell.edu

Abbey Jacoby
Bucknell University, amj006@bucknell.edu

Casey Stephenson
Bucknell University, cns010@bucknell.edu

Environmental Community Project: ENST 411

Revitalizing Turtle Creek Park

Michael Hardway, Ethan Harm, Abbey Jacoby, Casey Stephenson

Introducing Lewisburg and the History of Turtle Creek Park

Turtle Creek Park has been a part of the Lewisburg community for many years, becoming a privately-owned park open for public use in 2008. It is still known by many community members as the local "dog park"; however, it has been largely repurposed after its purchase by the East Buffalo Township while the Merrill Linn Land and Waterways Conservancy works on the conservation efforts (*East Buffalo Township Conserves Turtle Creek Park with Help from Merrill Linn Conservancy and Others*, 2023). Prior to the COVID-19 pandemic, a local church had bought the Turtle Creek Park and planned to build on it, clearing roughly 30 acres of the dog park. Forests were cut down to make room for buildings, soccer fields, and other recreational activities which the church would support. Fortunately, the church was unable to continue with the plan because of their loss in funding. The 30 acres of damaged Turtle Creek Park ecosystems allowed for invasive species to take over the park. Many of these species have taken over soils previously inhabited by native plant species and are still using a majority of the natural resources. In addition to this, the chopping down of the Turtle Creek forest has removed much of the habitats which were previously inhabited by native animal and insect species. When East Buffalo Township purchased the park in November of 2022, its goals were to try to reverse much of the damage that had taken place during the entirety of the church's ownership of the park property. This purchase was made possible by the Degenstein Foundation and the Department of Conservation and Natural Resources, who placed the property into the hands of local conservationists by providing a $300,000 gift and $695,000 grant. In order to prevent any development on the property, the Linn Conservancy was able to use its resources through a local land trust to place a conservation easement on the property which has enabled them to legally bind the land to its original uses and create plans to restore the natural habitat of Turtle Creek Park.

The Pennsylvania Department of Environmental Protection's interactive article titled simply "Turtle Creek " provides a full history of the restoration processes that have happened to Turtle Creek itself in the past several years. Lots of context is provided about the Susquehanna watershed, impaired streams in Union County, and areas of historic interest related to the park. The history of the Turtle Creek watershed itself is briefly explained and shows that man made changes in the area such as deforestation and the introduction of livestock have drastically altered the health of Turtle Creek (DEP). The full process of stream restoration is explained,

showing off the drastic change to Turtle Creek as well as the benefits provided by the restoration process. Knowing what has already been done to help Turtle Creek was extremely important for us to know in order to make sure that our work complemented and helped prior work and did not accidentally go against it.

Since its purchase by East Buffalo Township, the property has regained many of its original visitors back, and has also obtained donations in park benches, picnic tables, and trees in an attempt to reforest the area (Helwig 2023). These trees were planted with the aid of Bucknell's Chi Phi fraternity which worked with Jim Knight to reforest areas of the park lost during the Lewisburg Alliance Church ownership period. With the aid of the Spring 2024 Environmental studies and Sciences 411 class, Jim Knight and the Merrill Linn Conservancy have accomplished more of their goals via continued work with Environmental Studies and Science students and by encouraging the community to continue their involvement in the conservation of Turtle Creek Park. With the help of Brian Auman, the East Buffalo township supervisors are continually corresponding with the Linn Conservancy to accomplish continued conservation of the site.

Team Turtle Creek Project Goals

We current ENST 411 students, Abbey Jacoby, Michael Hardyway, Ethan Harm, and Casey Stephenson have chosen to work with Jim Knight, East Buffalo Township, the Merrill Linn Land and Waterways Conservancy, and many others in an attempt to revitalize Turtle Creek Park for a plethora of reasons. Three of us are majoring in biology, and two are majoring in environmental science, which makes much of the information and techniques relevant in Turtle Creek applicable to our courses of study. This project included heavy hands on work which allowed us students to leave a memorable and impactful influence on the Lewisburg community. Post-graduation, the Turtle Creek Project will provide a continued source of outdoor recreation and conservation for local species regardless of our presence on campus. In addition, several of us will be pursuing environmental studies and sciences careers after graduation, where we will use our skills and knowledge obtained from the Turtle Creek Park experience. Overall, the park revitalization project provided an opportunity to connect with the local natural ecosystem in ways we have not experienced before, and also allowed each of us to build unique

connections to figures important in the field of conservation and environmental studies here in Pennsylvania.

Community Partner Goals

Our community partners had three major goals. Those goals, in order of most to least important are: dealing with stormwater issues onsite (large amounts of runoff and poor drainage make several areas in the park consistently muddy and unusable), invasive species removal (figuring out methods for removing invasives and putting those plans into action), and restoration and reforestation of areas of the park. While these ideas do all go hand-in-hand and interconnect in one way or another, dealing with the runoff was the most pressing issue. Some progress had been made on all of these goals prior to our involvement, giving us a foundation from which to work.

Literature Review

In our search for methods and tasks which would help to complete the goals of our community partners, much literature was reviewed and analyzed in an attempt to gain a better understanding of the issues at hand in Turtle Creek Park. We were able to find the importance of minor details like leveling out the base of the boardwalk, dealing with the potential of the wood possibly sinking into the ground, and also the issue of installing the puncheon style boardwalks while still allowing for a flow of water underneath (Shields 2021). Within our research, we examined other wet trail restoration projects already in effect and working. We learned that the best base layers for these programs include things like dry sand/silky sand or a gravel called pea gravel (IOH 2024). These function best as a thin layer beneath the punch rod and can handle the leveling out but also act as a filter stream for the water to continue flowing underneath. Because Jim Knight and his partners were interested in repairing storm damage from flooding and runoff, removing invasive species, and reforesting the once rich landscape of the park, the research each group member has compiled encompasses both the background of these problems and techniques to aid in solving them.

Storm Damage and Stream Runoff

In the literature review for solutions to storm damage and runoff, there were several methods and practices which can be used to mitigate future and past damage. In the case of stream restoration, there must be a connection between the structure and its functionality. One

method to eliminate the stream runoff is to support the sides of streams with a wood fixation. Doing this allows the functionality of the stream to increase marginally by removing 40% of nitrogen, phosphates, 27% of nitrates, and other harmful chemicals (Thompson et al. 2018). When the stream has the proper structure, it is able to filter the water and allow it to support its ecosystem, as well as being safe for recreational uses. This is applicable to the Turtle Creek Park because the stream has flooded much of the ecosystem and caused decreased water and soil quality. It would be interesting to note in our project how the water quality changes after fixing the structure of the stream. In addition to this strategy, another source references the importance of researching ecological pressures, pressures from population density and human interactions, and watershed pressures (Verdonschot & Verdonschot 2022). The authors suggest that mapping these stressors can be helpful in restoring a stream because they can show what a stream will need to increase its productivity and quality of the ecosystem. In the case of ecosystem pressures, Turtle Creek will likely experience higher concentrations of chemicals because the area needs to be reforested, so there will need to be mapping that will allow for the increase in quality of the stream in correlation with the reforestation. Connecting reforestation, flood mitigation, and invasive species will help to increase the park's quality of soil and water which will allow the natural area to repopulate with native plant and animal species successfully.

The EPA's *Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement* provides a general overview of green infrastructure in parks, including some methodology for how to deal with runoff and drainage problems. Green infrastructure enhances recreational value, creates attractive park features, enhances social and environmental equity, reduces maintenance, improves drainage and water quality, provides economic benefits, helps educate the public, and benefits the overall environment (EPA 2017). This guide provides a general overview of a full process of adding green infrastructure to a park, from surveying problem areas, to finding funding and partners, to actually implementing planned solutions and maintaining them, while providing case studies to show the benefits of green infrastructure in action in the real world. In addition to the drainage solutions proposed by our partners, another useful method is trail drainage features, or TDFs, as suggested by the National Park Service. According to the NPS, "A trail drainage feature or TDF is a purposeful arrangement or installation of any material (most commonly rock, wood, or soil) on or adjacent to the trail tread that aids in intercepting continuous surface runoff and diverting water from tread surfaces"

(National Park Service). These TDFs could benefit Turtle Creek Park as a relatively simple method of water diversion that is natural and can be installed and adjusted relatively easily to maintain maximum effectiveness while remaining relatively unobtrusive to park goers. The US Forest Service and USDA provide guidelines on the benefits of puncheon boardwalks and how to properly construct one, a potential key method for our restoration efforts ("Trail Construction and Maintenance Notebook, 0023-2839-MTDC, Trails in Wet Areas"). The puncheon boardwalks are a smaller, more cost effective version of the original 6 foot width boardwalk. They only take up around 2 feet of space and also allow for bikes and walking on the muddy paths. The Forest Service additionally details the many downsides of corduroy roads which is necessary information to show our partners that corduroy roads should not be considered as a permanent solution (or potentially even a temporary one) due to the costs involved, impact on the environment, and the ease at which these roads break up ("0723-2804-MTDC: Wetland Trail Design and Construction 2007 Edition").

Wetlands are one of the most important biomes that combat the effects of climate change. The article emphasizes the need for sustainable management practices to preserve wetland functions and water quality. It proves that repairing floodplains through reconnected channels allows for easier drainage (Newcomer Johnson 2014). This is a different approach than what previous Turtle Creek Project groups have done in the past. Allowing water drainage to flow under the boardwalk to ensures that there is minimal flooding. Another method is to build sediment detention ponds on the outskirts of the park. This would allow wetlands to be protected from contaminants that flood into the park (Brydon et al. 2006). Detention ponds stop runoff from going directly into wetlands as a better option for a sustainable future. This type of project would need to be treated and maintained through community efforts long after it is installed.

The Victorian Stormwater Committee in Melbourne Australia distributed a report that outlines comprehensive strategies for managing urban stormwater and protecting water quality (VSC 1999). These strategies include pollution prevention, erosion control, and sustainable drainage methods. This source also encourages the use of green infrastructure techniques and stakeholder cooperation, highlighting the value of including stormwater management into urban planning and development in society these days. These findings are essential to the design of our project because they provide practical guidance on how to lessen the damaging effects that urban stormwater runoff has on ecosystems. Furthermore, De Wet, Richardson, and Olympia's (1998)

work illuminates how historical land use shaped present biodiversity and ecological processes by digging into the complex interactions between historical land use and current ecological dynamics in an urban wilderness undergoing recovery. In addition to highlighting holistic approaches to urban conservation and the potential for ecological restoration to improve urban resilience, this research shows the significance of taking past land use patterns into consideration in conservation and restoration initiatives.

Invasive Species Removal

Wetland and forest restoration are dependent on the soil quality and nutrient abundance which is needed for plant life. In order to properly manage and remove invasive species, there are specific techniques that are used in order to prevent further invasives from entering the Turtle Creek natural landscape. One of these techniques is to remove not only the plant, but also the plant's biomass to prevent it from re-establishing itself and continuously removing nutrients from the soil (Lishawa et al. 2019). At Turtle Creek Park, much of the ecosystem has been taken over by invasive species which are stealing the nutrients which are used by native species, and overrunning the Turtle Creek natural habitat. In order to completely rid these ecosystems of the invasive plants, there has to be a more aggressive mechanism to remove the invasive plant and their remaining biomass so they can no longer dominate the ecosystem. In order to accomplish this, removal must include deep soil which requires more effort and may take longer, but will likely prevent their return. Using this strategy could allow invasive species removal at Turtle Creek to be more successful. There are many other strategies which allow for long term removal of invasives. It is important to involve certain community members to affirm that the efforts will be successful. In areas like community parks, this is far more important because of the consistent human interaction the park experiences. A source which conducted an experiment at a local park in Australia found that when community stakeholders were involved in the process of invasive species removal proved the process to be far more efficient (Moon et al. 2015). This is due to the community stakeholder's connections to community members and to resources which can help speed up the process, and allow for increased funding. This strategy could be useful in the Turtle Creek project because they have ties to the Linn Conservancy which has connections to regulatory specialists and ecologists that may be able to help both in funding and in invasive species removal strategies.

The Pennsylvania Department of Conservation and Natural Resources has compiled a full list of plant species deemed to be “invasive on state lands” (DCNR 2024). This list has been broken into several subcategories for trees, shrubs, vines, grasses, herbs, and aquatic plants. Each plant has its own easy to understand fact sheet that provides vital information about each plant such as a description, background, range, habitat, spread, threat, level, control methods, and look alike plants.These fact sheets could be invaluable for our work at Turtle Creek simply as a quick and easy reference guide for identification and control, or as a guide should we decide to create some form of informative signage for the park.The Pennsylvania Department of Agriculture also has a list of invasive species that extends outside of plants to pathogens and animals. Much like the DCNR list, this list “is provided to inform development of regulation, policy, and education to protect our agricultural and natural resources” (Pennsylvania Department of Agriculture). While not as informative as the DCNR’s list, the PA Department of Agriculture Invasive Plant list does include a “score” for each species based on how much of a threat it is.

The *Commonwealth of Pennsylvania Pennsylvania Invasive Species Council Aquatic Invasive Species Management Plan* reports the impact invasive species have on aquatic ecosystems and wetlands. The plan identifies species that threaten diversity along with mechanisms to combat the problem at hand. As thousands of acres have been attacked by invasive species, this plan believes that digging deep to remove species by their entire roots is the best way to eradicate the problem (Council, P. I. S. 2006). This involves removing larger portions of the soil and replacing it with new soil so the chances of it spreading again are much lower. The *Rapid Response Plan and Procedures for Responding to Aquatic Invasive Species in Pennsylvania Pennsylvania Invasive Species Council* details a rapid reaction to invasive species in a wetland. It outlines identifying the species leading to risk assessments followed by evaluations of the site itself to see what organisms they are affecting (Council, P. I. S. 2014). It states different response options to different species with clear objectives on how they want to accomplish their goals. Reichard, Liu, and Husby's (2012) paper explores the possible hazards of managed relocation and issues a warning against unintentionally aiding the spread of invasive species into new areas. It raises questions regarding the introduction of non-native species into conservation initiatives meant to preserve rare plant species. The findings provided by the authors urge us to carefully examine unintended effects in the project design, stressing the

importance of comprehensive risk assessment and flexible management techniques. We have taken into consideration the response we will get from the community whether it is well received or disliked. There are neighbors who could have a say when deciding if a path is restructured or if we can touch certain plants or bushes. This source enables us to critically assess the ecological consequences of conservation efforts by offering insightful viewpoints to the literature evaluation. Likewise, Sherrill et al. (2022) promotes the preservation of native plant diversity while talking about integrated management approaches for invasive species. They emphasize how crucial it is to use strategies that both combat invasive species and promote native vegetation.

Reforestation Techniques

Reforestation is a process which has become more popular in the age of the Anthropocene. Due to continued development and increasing global population, there is a consistent need for more homes, shopping centers, entertainment buildings, and many others. In the case of Turtle Creek, much of the land was deforested for the construction of a church complex, soccer fields, and a gymnasium (*East Buffalo Township Conserves Turtle Creek Park with Help from Merrill Linn Conservancy and Others*, 2023). In a related article, the authors Sheeren, Monteil, Ladet, and Balent discuss the importance of human interactions with their environment. Change in forestation in this example is compared to the mountain landscape in France, where the authors evaluated how politics and social life impacted the quality of the environment. The mountain area described in this analysis was used for agricultural purposes, which has the possibility to deteriorate the quality of the soil (Gibon et al., 2010). This could be applicable to the Turtle Creek project because it is also in a primarily agricultural area, so the soil could have similar quality to that mentioned in this article. The perspective mentioned on people's relationship with their environment is also relevant to reforestation techniques we may be using in Turtle Creek, especially considering Turtle Creek is regularly trafficked by humans for recreational purposes. By understanding the deep relationships humans have with their environment, it allows us to learn more about how certain reforestation techniques could be more or less effective in the Turtle Creek area by evaluating the connection of agriculture in nearby areas. The ecosystem of Turtle Creek is unique because much of it is a wetland from stream flooding and storm damage. Because of this, there are few processes which allow for a higher yield of healthy trees after reforestation. One source suggests one of these factors is the quality

of the soil, which should be wet in order for the planted trees to survive after they are placed into the ground (Preece et al., 2023). Planters should also soak the roots of tree saplings in water while they are in their tubes in order to assure continued survival. By understanding the methodology of reforestation and the sociological implications of humans' interactions with their environment, reforestation may provide an efficacious outcome to the suffering ecosystem of Turtle Creek Park.

Susan Cook-Patton, Senior Forest Restoration Scientist for the Nature Conservancy, provides a general overview of reforestation in her article "Reforesting the U.S.". While this article is not extremely detailed, it explains the basics on the process and links to numerous other resources on the topic.

The article, "Effects of land use and forest management on soil carbon in the ecoregions of Maryland and adjacent eastern United States", is a data analysis detailing the importance of soil conservation in the fight to preserve wetland's soil organic carbon (Nave et al.,2019). It becomes evident that intensive harvesting practices have led to a significant depletion of topsoil, accentuating the pressing need for sustainable land management strategies. The results showed the benefits of these practices allowing for flourishing reforestation. Planting mulch along with the eradication of invasive species can show the same results at Turtle Creek. *Wetland and Riparian Stewardship in Pennsylvania*, describes restoration of the delicate ecosystems that are a part of the Chesapeake Bay watershed. This source explains the necessity of cultivating resilient ecosystems capable of withstanding environmental change (Landowners, L. G., 1997). This cultivation is accomplished by establishing riparian buffers, stopping toxic runoff from entering habitats, and the removal of invasive species.

Veldkamp et al. (2020) analyze the complicated impacts of deforestation and reforestation on tropical soils in this review article, focusing on changes to soil characteristics, nutrient cycling, and ecosystem functioning. It depicts the complex relationship between changing land use and soil processes, including both the negative effects of deforestation and the positive effects of reforestation as a means of restoring soil. Within Central PA and our site specifically, we are able to use this data as on our site there has been a transition of use of the land from a dog park to a more traditional park. We also see a result of deforestation in both the article and our site as we attempt reforestation. The positive effects of this on the soil can be seen when showing the nutrient uplift according to the Veldkamp et al. The levels of nutrients in

Turtle Creek are inconsistent depending on land use but what is seen is how deforestation decreases nutrient levels in the soil. We are hoping to counter this with reforestation efforts like the planting of the Oak Savanna in the Spring of 2023. Continuing this project will allow for continued nutrient growth in the unhealthy soil. Veldkamp et al. sheds information on the long-term ecological consequences of changing land use and the significance of reforestation in soil conservation initiatives, which is helpful in designing our project. Furthermore, by showing the need of taking soil dynamics into account in ecosystem management initiatives and promoting sustainable land-use practices, we hope to instill the desire to improve the Turtle Creek ecosystems in community members. Accordingly, the chapter by Yue and Burley (2021) provides an actual case study of how predictive modeling might be used to direct reforestation and agricultural reclamation projects, using Clearfield County, Pennsylvania, as an example. The authors prove the effectiveness of predictive models in determining the suitability of a piece of land and predicting the dynamics of vegetation by employing remote sensing data and geographic information systems (GIS). This source advocates for reliable baseline data and the integration of socio-economic elements in land-use decision-making processes, reiterating the importance of integrating technology and spatial analysis methodologies into conservation planning and monitoring activities.

Soil Sampling

Soil sampling techniques are relatively simple, but there are still specific tools that need to be used, such as trowels and coring devices (Ohio State University). Ohio State University provides a relatively easy to follow guide on how to properly sample soils that we will be using as a basis for our soil sampling work. The aspects that OSU recommends testing for are “pH, structure, texture, density, nutrients and percolation” (Ohio State University). In addition, there are some indicators present outside of the soil itself that will indicate soil health, such as leaf color (Ohio State University) that will be helpful once spring comes and there is more greenery present in the park.

Soil sampling can show us the benefits of wetlands on soil health. When river water interacts with the soil in the river floodplain, it can perform denitrification on the water, which is “the anaerobic microbial conversion of nitrates to nitrogen gas” (Orr et al., 2007). If these nitrates remain in the water, eutrophication can happen downstream, potentially leading to algal

blooms and dead zones. Maintaining these natural wet conditions is important for both the health of the land itself as well as the river.

Invasive species can also have significant, long-term effects on soil health. "Successful aboveground restoration does not necessarily mean successful belowground restoration" (Unger et al., 2021). Invasive plant species, even when properly managed and removed, can drastically alter both the microbial and molecular composition of the soils they have invaded for upwards of multiple years post-restoration (Unger et al., 2021).

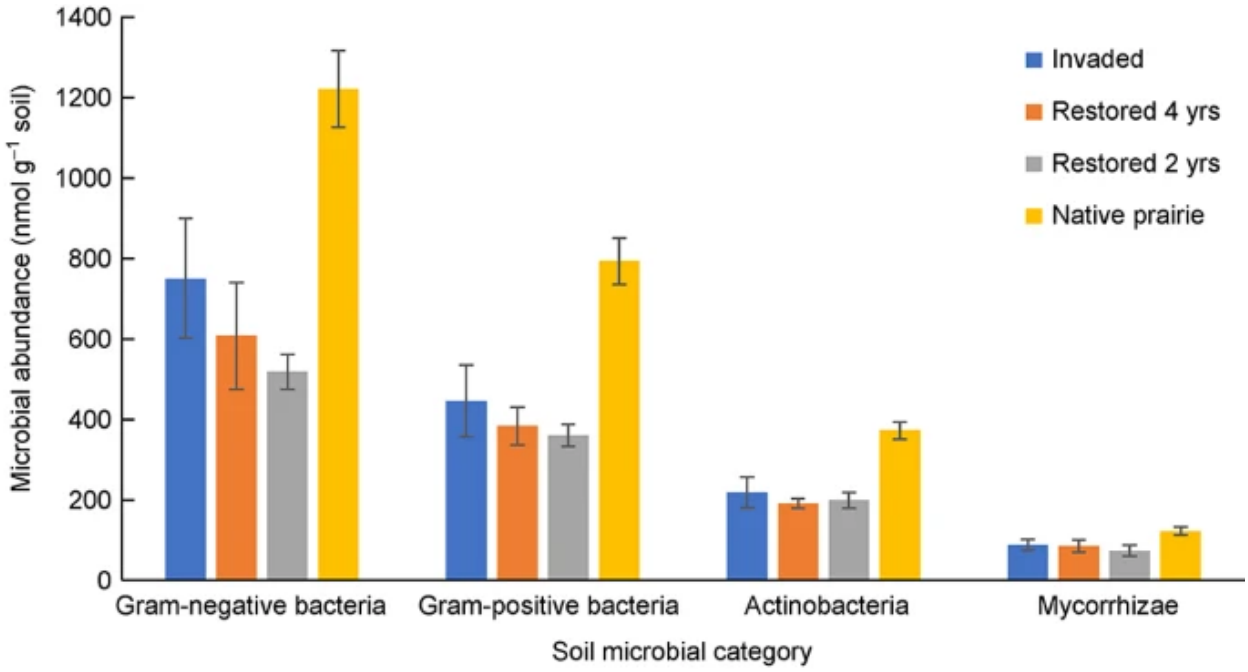

Figure 1. Bar chart showing microbial abundances from several prairie sites in Missouri at differing levels of restoration. The drastic change between native, invaded, and restored prairie microbial abundance is clearly visible (Unger et al., 2021).

Low-lying and concave landscape features are subject to soil saturation from heavy or prolonged rainfall events (Unger et al., 2009). Central Pennsylvania is no stranger to weather like this, especially during the spring months. This soil saturation, when combined with microbial activity, can lead to depletion of oxygen in the soil, as well as change in concentrations of several other nutrients which can even reach toxic concentrations for plants (Unger et al., 2009). While plants adapted to flood conditions are able to deal with these changes, plants that are not adapted cannot deal with them (Unger et al., 2009). To conclude this soil sampling overview, soils are both extremely sensitive and extremely important environments not just for

their immediate areas, but even for areas more distant via aspects such as denitrification. When planning on making any sort of alterations to a soil, even ones perceived as helpful, the environment belowground needs to be thought of just as much as the one aboveground.

Project Tasks

Turtle Creek Park has significant issues with water runoff and water retention onsite. Twenty five "trail wet areas" have been identified where sections of trail do not drain properly, leaving the soil extremely saturated and muddy and therefore less than ideal for walking and hiking for park goers. The trails range from twelve feet wide at maximum (for ADA accessibility) to only six feet wide at minimum (Hanniford and Auman). The biggest priority for Turtle Creek park is coming up with a plan for resolving this drainage issue, and potentially implementing some of that plan. In the past, mulching or spreading gravel on the surface of the trails has been used as a cheap but temporary solution. Eventually, the mulch will decay or the gravel will sink into the soil, and the process needs to be restarted. Drainage pipes have also been put in place in a few locations on site but several of these pipes have become exposed over time.

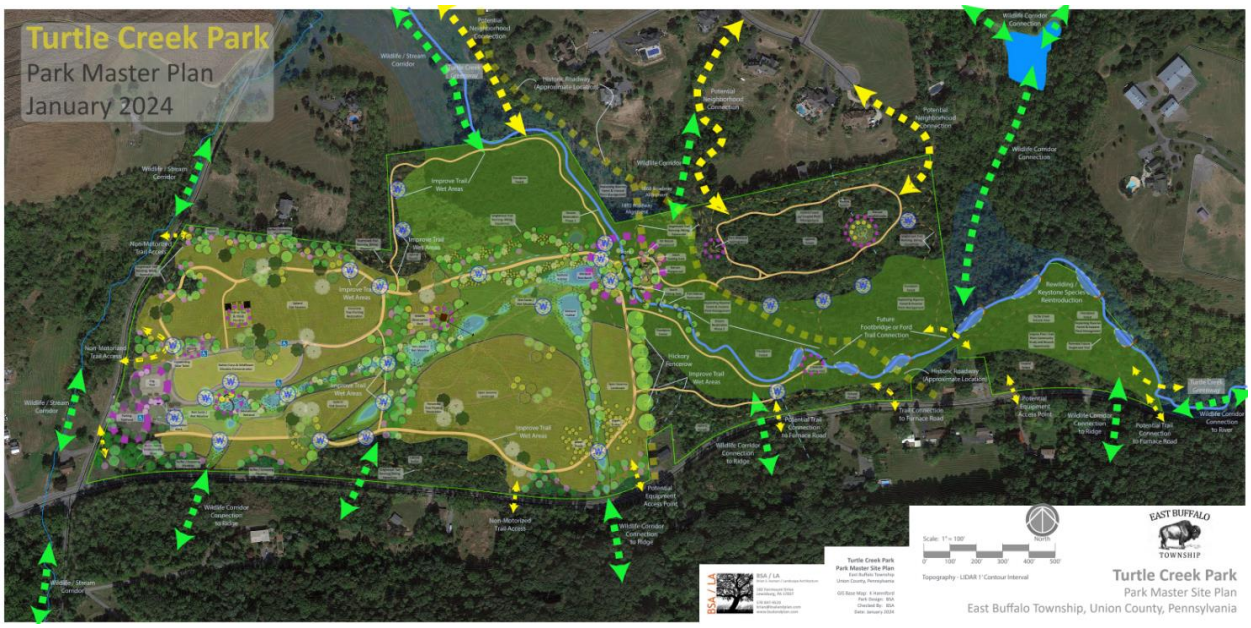

Figure 2. Master plan for Turtle Creek Park. Circled "W's" indicate drainage problem areas (Hanniford and Auman).

As there are so many problem sites within Turtle Creek Park and we overall have a limited timeframe, we planned to specifically focus on several sites in the northern section of the park that have been highlighted as problem areas by our community partner, Jim Knight. A loop of trail in the northernmost section of the park was selected as our work site as it has the worst muddy trail issues. We planned to make trips out to Turtle Creek park to take measurements of the problem areas in order to determine the exact dimensions of these areas, which allowed us to make more accurate estimates for the costs of solutions. Being onsite has allowed us to assess the severity of the water problem as well as the conditions surrounding the problem areas, allowing us to best determine the most effective solution for each area in particular. While we had originally planned to conduct an analysis on soil quality, the confirmed funding from the Degenstein Foundation changed the timeline and the main goal of the project. Instead of conducting a soil experiment, we turned to certain publications which provide data suggesting trends in soils which are inundated with invasive species.

In Lewisburg, Pennsylvania, planning the removal of invasive species including Autumn Olive, Multiflora Rose, and Honeysuckle (Figure 2) requires an extensive plan that includes several important actions. First and foremost, it is essential to correctly recognize the species and its location and evaluate its amount and spread. To identify the regions impacted by these invasive species, mapping procedures and field surveys must be carried out. Research into the biology and ecology of the targeted species then affects the decision of appropriate removal techniques. For lesser infestations, physical techniques like hand pulling and cutting work well; bigger areas can

require the use of mechanical tools like brush cutters or mowers. Selective herbicides used in chemical management techniques can successfully target invasive plants with the least amount of damage to native vegetation (Reichard). In order to prevent unexpected ecological impacts, biological management strategies, such as the introduction of particular insects or bacteria, may also be carefully evaluated. In order to guarantee the long-term success of removal operations, the strategy places an intense focus on the importance of ongoing monitoring and maintenance, and community involvement.

Figure 3. Examples of invasives present in the park, from top to bottom: autumn olive, multiflora rose,

For invasive species management to be successful, cooperation with volunteers, stakeholders, and local community organizations is essential (Moon et al., 2015). Participating in outreach programs, volunteer workdays, and educational courses develops a sense of community ownership and accountability. Collaborations with governmental organizations, academic institutions, and environmental organizations promote sharing of knowledge, resources, and financial opportunities. The adaptation of removal efforts and management strategies to changing ecological conditions is ensured through ongoing assessment of monitoring data and stakeholder feedback, as well as adaptive management.

For reforestation, the park currently has a nursery of trees present onsite. The trees present within this nursery are still much too small to be placed out in the park, and need to be left to grow within the protected space of the nursery in order to prevent them from being damaged by storms or eaten by deer.

Methods

Step 1: Grant Proposal for Construction Materials

The Turtle Creek Revitalization project required many different strategies. The first of those methods involved creating a grant proposal for the Degenstein Foundation. The Degenstein Foundation has been an avid supporter of the park since its purchase back from the church in 2022, and community partner Jim Knight wanted to prioritize their involvement in the project. In order to proceed with the boardwalk building and mulching of the wet areas, we needed as much funding as possible to get materials necessary for the construction. As a team, we worked with both Jim Knight and Char Gray to discuss the priorities of this semester's Turtle Creek Project

and wrote a proposal that would convince the organization to help fund the goals of Jim and our project group. Most of the proposal suggested the need for boardwalk construction in flooded areas of the park in order to increase visitor's experience. The grant proposal was submitted to the Degenstein Foundation on March 1st and included information about the items the Turtle Creek project requires funding for, and information involving the future maintenance required. On Friday, March 22nd, we learned that the Degenstein granted us $5000 worth of funding for the boardwalk project.

Step 2: Literature Review

Instead of doing research on soil quality as we had originally planned, we decided to turn towards a literature review for results on soil sampling. This is because we were unsure as to whether evaluating soil quality would do anything to support our community partner's goals for the project, and also that the results of the experiment may provide little insight into future invasive removal and reforestation plans for the park. We looked to assess the soil quality in areas with dense invasives and deforestation. Researching soil quality in areas that are overrun with invasive species also gave a strong reason to why there needs to be change in Turtle Creek in order to maintain a sustainable future. Because the boardwalk construction took up a majority of the time and funding our project group had this semester, we chose to address the issues of invasive species and reforestation by researching ways in which Jim Knight and our other community partners can address these issues in the future. In addition to this research, Brian Auman has conducted a thorough analysis of the park and constructed a step by step plan to address the drainage, reforestation, and invasive species issues for the next several years.

Step 3: Pricing of Lumber and Other Equipment

Once the funding was approved by the Degenstein Foundation, we needed to move as quickly as possible to order lumber so the construction phase of the process was able begin. In order to avoid excessive expenses, we decided it would be best to obtain the lumber from a local lumber yard instead of a corporate industry like Lowes or Home Depot. In doing this, we would be able to get untreated, raw lumber for a much cheaper price. This is because the local lumber yards are willing to give students associated with Bucknell University a discount per foot of lumber, and also provided us with a tax exemption. The local lumber yard we chose to work with for this project was Northeast Softwood, who gave us a final price of $2,002.73. In addition to ordering the lumber for this project, we purchased galvanized decking nails from a local

hardware store. These nails are textured and provide better long term odds of the puncheon boardwalks withstanding weathering. In addition, there are some tools like wheelbarrows that we gained access to through volunteers, the town, and our community partners, and we planned to rent some battery powered saws, hammers, and other tools from a local business called West Branch Rentals in Lewisburg. While we aimed to use these battery powered tools for potential onsite woodwork, the West Branch Rentals had no battery operated tools available for rent, only a portable generator which we did not feel was necessary for the project. Lucky, Jim Knight had a battery powered chainsaw that worked perfectly in trimming some edges off of a few boardwalk pieces, and we only needed a few gardening hoes, shovels, and wheelbarrows which were graciously provided by Brian Auman, Jim Knight, Char Gray, and East Buffalo Township.

Step 4: Visits to the Turtle Creek Site

After the lumber delivery was placed, our team, along with Brian, Jim, and Char made three separate visits to the park. In the first visit, the Turtle Creek Project team went out alone to evaluate the state of the flooded trails to estimate measurements and propose building ideas. In the second visit with Jim and Char, several plans were discussed in an attempt to address the flooding issues at Turtle Creek Park. After another weekly meeting, we revisited the site with landscape architect and Turtle Creek Park Trail Steward, Brian Aumann, to take the official measurements of the boardwalks. These measurements were used to place the lumber order. In this visit, our project team also had the opportunity to discuss boardwalk methods with Brian, who suggested the proper ways to build the puncheons in the flooded area. The fourth visit to the park was after the lumber was delivered to the construction site, which our student project team used to develop a step-by-step method to building the boardwalks. On Friday April 5th, we met with Brian Auman at the site to construct the first parts of the boardwalk so that we would have an idea on how to build them at the volunteer event. After this Friday “trial run”, the following meetings at the flooded site at Turtle Creek were both volunteer events where we constructed the puncheons.

Step 5: Discussions with Bucknell Students, Professors, and Community Stakeholders

Throughout the length of the project, one thing that our student project team learned was how important community stakeholders are to large projects like the Turtle Creek boardwalk project. These identified stakeholders provided our team with the necessary background knowledge about the Turtle Creek park. One of these stakeholders, Char Gray, had lots of

historic background about the park prior to its conservation under the Linn Conservancy. She also provided us with ways to outreach to the community, and provided many tools that we were able to use for the construction of the boardwalk as well as wood chips and mulch through her connections to East Buffalo Township. Brian Auman was a pivotal aspect of our project, and helped us through every construction phase of the project. His knowledge about landscape architecture allowed us to successfully build the boardwalks and he also graciously took extra time to show us how to build examples prior to our planned project construction days. Brian also has extensive knowledge of the park due to his future park plan he created, and he is also the trail steward for the park under the Linn Conservancy. We could not have completed the project without the assistance from the Bucknell football team and with the help of our professor, Amanda Wooden. She has provided us with ideas and knowledge which has greatly helped move our project forward through the semester. Lastly, our project partner Jim Knight has provided continuous support as we completed our project. He continuously reassured us that our efforts in the project were exactly what he wanted to come from this year's Turtle Creek Project, and also connected us to East Buffalo Township for necessary supplies. Jim allowed our group to have some creative freedom throughout the project and also allowed us to pursue our personal interests along with his own interests in the project completion.

Step 6: Recruitment of Volunteers

On campus, there are several organizations that our team has access to which had potential to provide us with student volunteers. One of these organizations is Epsilon Eta. Epsilon Eta is an environmental honor's society on Bucknell University's campus. The organization aims to organize students who are passionate about sustainability and the environment and instill these ideas in other students on campus by organizing social and service events. In order to be a member of this organization, students must work a certain amount of service hours every semester, so the Turtle Creek Project Team hoped to provide an event that organization members can gain community service hours for. Because the project is also environmentally friendly and directly related to some of the goals of the organization, it piques the interest of many students involved. In addition to this organization, fellow Turtle Creek Project team members Casey Stephenson and Michael Hardway worked with their coaches and teammates to get volunteers at the April 7th and April 14th events. The Bucknell Football team helped lift hundreds of pounds of lumber down to the construction site so that we could build the

boardwalks without worrying about moving the lumber from the storage site, uphill of the Northern Trails. These team members also helped construct the boardwalks, in addition to another Bucknell student who had seen the advertisement and wanted to help out.

Step 7: Building the Boardwalks

An extremely simple solution suggested by our project partners was trail relocation (Hanniford and Aumann). Simply adjusting the course of the trails to avoid the problem areas and move into areas that drain more easily costs little to no money and could be carried out in days to weeks. However, there are problems with this method. Trail relocation may simply not be feasible: an early concept for fixing the trails in the north section of the park was simply to move them to the right to higher, drier ground. Unfortunately, this came extremely close to the edge of the park's property and might have crossed the property line in some places, so it was deemed a non-usable solution. Trail relocation can also be highly labor intensive and potentially destructive if not done carefully and correctly. No trail relocation was carried out by our team, but may be a valid solution in other areas of the park.

Another suggested solution was a corduroy trail (Hanniford and Aumann). This design involves logs running parallel to the trail along its sides, and a "bridge" of logs to be placed perpendicular on top and attached, or these logs are placed directly onto the ground with no support below them whatsoever (US Forest Service). The United States Forest Service does not recommend this method, citing runoff alteration, wetland damage, significant material cost, and significant maintenance costs as major negatives and that this method is not sustainable (US Forest Service). It can be used as a temporary stopgap however. We did not use corduroy trails in our project due to the reasons outlined above.

Puncheons are a similar but significantly better solution, consisting of thin wooden walkways elevated above the trail surface (US Forest Service). This method only covers a portion of the trail, allowing natural drainage to occur and for the actual ground to remain exposed while keeping the path fully functional in both wet and dry conditions, but is unfortunately less accessible to someone who is physically handicapped.

Boardwalks are another solution, providing a well-established path wide enough for either several park goers or someone who is handicapped as well as allowing for drainage. However, boardwalks are by far the most expensive solution and should only be used sparingly (Hanniford and Aumann). Additionally, boardwalks would be far too time consuming for our

limited building opportunities and were a potential obstacle for mowers and were therefore not used as a solution.

An alternative solution discussed by one of our community partners, Brian Aumann, is trail drainage features. These are “a purposeful arrangement or installation of any material (most commonly rock, wood, or soil) on or adjacent to the trail tread that aids in intercepting continuous surface runoff and diverting water from tread surfaces” (National Park Service). These trail drainage features are relatively easy to install, are not overly intrusive on the paths themselves, are designed in such a way that they interact with runoff instead of blocking it, and can easily be altered to suit changing park conditions.

Simply laying out mulch was another method considered, as it is a simple and cheap process. However, we observed that this strategy had been attempted elsewhere in the park and was unfortunately not successful or was only a short-term solution as the mulch simply sank into the mud or rotted quickly.

The installation of plastic piping to help reroute and control flow was also considered. However, this solution was deemed too time consuming and not environmentally friendly. Additionally, the plastic and metal piping already installed in the park showed that these drainage controls can become easily clogged and nonfunctional due to numerous factors such as plant debris, sediment, animal debris, and human made waste.

Figure 4. Examples of trail drainage features made of stone (left) and wood (right) (U.S. National Park Service.

The final solution decided on for this project was puncheons. The design used in Turtle Creek park consists of two 2 foot by 12 foot by 12 inch boards laid along the length of the trail. They are placed on top of three 6 inch by 6 inch by 3 foot support beams to ensure the structure is sturdy to withstand wear and tear while remaining elevated out of the mud to allow for drainage and to help slow rotting. Gravel was added below the beams to prevent the puncheons from sinking over time. We nailed the walkway boards into the support beams with four nails per support, twelve nails per walkway board total, or twenty four nails per individual section of puncheon. These puncheons were placed on the side of the path to make room for lawn mowers and other machinery that will need to travel through the park for maintenance, as well as ensuring that the path is still fully functional in both wet and dry conditions. These boardwalks were chosen because they require less knowledge and experience in order to build successfully, allowing our group to quickly learn the process and make it accessible to volunteers. This also allowed for the puncheons to be constructed at a relatively fast rate. Another consideration was cost. Since the puncheons consume relatively little wood, large amounts of trail were able to be repaired without completely exhausting our budget.

Project Timeline

February 16, 2024: First meeting with Jim Knight, the leading community partner of the Turtle Creek Park project. We discussed the goals of the project and short term tasks which needed to be accomplished. The idea of a grant proposal was presented, and the team spent the next week totalling estimates for supplies.

February 20, 2024: Turtle Creek Project Group evaluated the needs of Mr. Knight, and completed extensive research on the financial requirements of the project for the Degenstein grant proposal.

February 23, 2024: The team met with Jim Knight again to discuss the ideas for the grant proposal and a tentative budget and plan for the boardwalk construction in early spring.

February 25, 2024: The Turtle Creek Team traveled to the site to evaluate the storm damage referenced by Mr. Knight and the plan created by Brian Auman. Notes and measurements were taken to determine early building strategies.

February 26, 2024: The team traveled to Turtle Creek Park with Jim Knight to gain his perspective on the damage and goals attached to the project. The team worked with Jim to discuss how the grant will be used.

March 1, 2024: Submitted official grant proposal with Mr.Knight for the Degenstein Grant for the amount of $5,000.

March 5, 2024: The group worked to complete the final draft of the project design and submitted it to both Jim and Professor Wooden.

March 7, 2024: The group emailed Mr.Knight and discussed details about our design proposal and what things he feels we should work on and where we have confusion.

March 19, 2024: Standard group meeting, discussed interim draft report.

March 22, 2024: Degenstein Grant funding received, full $5,000. Discussions about finalizing boardwalk design (puncheons) have taken place, as well as what materials will be used. Multiple lumber companies were contacted for rough estimates on quotes for lumber, plans were made to finalize measurements on 3/24/24.

March 24, 2024: The Turtle Creek Group traveled to Turtle Creek Park once again to finalize measurements for the flooded areas being addressed. The total length of trail being serviced was roughly 250 feet long along the northernmost trail loop in the park and is split into four sections. Lengths were marked and further planning was done regarding wood delivery and work days.

March 26, 2024: The group traveled to a lumber yard to do final testing of different lengths of lumber to determine the amount of structural support needed as well as placing an order for the lumber.

March 29, 2024: Meeting with Mr. Knight, further finalized work day plans.

March 30, 2024: A local resident contacted by Char Gray came in with a brush hog to help clear brush along the edge of the trail to facilitate the building process.

April 4, 2024: Lumber delivered to Turtle Creek Park, one of the community partners was present to help facilitate lumber delivery.

April 5, 2024: Initial work day on puncheon boardwalks with the Turtle Creek Group accompanied by Brian Aumann. Intent was to learn how to build the boardwalks correctly and efficiently to maximize progress on group work days.

April 7, 2024: Day for volunteer work on boardwalks from the Bucknell Football Team and other volunteers. Members of the Standard Journal attended to interview for a small article in the paper.

April 14, 2024: Day for volunteer work on boardwalks with help from the Bucknell Football Team as well as community members.

April 16, 2024: The Turtle Creek Team met to discuss final project report coordination and writing.

April 19, 2024: Draft project presentation and workshop.

April 23, 2024: Final project presentation at MacDonald Commons.

Findings and Results

Boardwalk Construction Findings

In discussion with community partners, stakeholders, and visiting the Turtle Creek Project, there are several findings which have become evident in our work and research at the park. The first of these is the idea of the boardwalks. In exploration of the park property, it became evident that the northern end of the park is far more flooded and damaged than other parts of the park. Much of the trails in this area are so wet that they are not capable of being walked on because they are saturated with water. Much of this has to do with the elevation of the land in comparison to other parts of the park, but this part of the landscape is also a very healthy wetland home to native species like silky dogwood and many others. After an interview with Brian Auman who is the trail steward at the park, and also the creator of the park restoration plan, he mentioned that building the boardwalks in this region could cause some concern because of the health of the wetland in these northern areas. He mentioned that because this is one area of the park that remained untouched during the deforestation of the park, it maintains lots of the native species which once existed throughout the park.

In conducting research on boardwalk type, we have also established which boardwalks will and will not work for the Turtle Creek Park. Originally, we had discussed in the literature review that puncheons would be a cost-effective and environmentally friendly solution to the flooding problem in the north end trails. In conversation with Char Gray, Jim Knight, and Brian Aumann, we established that these would be the simplest way to alleviate the flooding issues occurring in the park while also providing space for the township mowers to continue to mow

during the summer when the trails are dry. The puncheons also provided a type of boardwalk that not only allows for water to continue to flow underneath, but also covers a small area of the trail, allowing for the wetland habitat to be slightly disrupted by the construction. During our construction of the boardwalks, Aumann helped us maintain much of the natural wetland features by leveling the boardwalks and allowing water to run underneath them, assisting the water flow of the wetland.

Figure 5. An example of a puncheon boardwalk mirroring the structure of the boardwalks planned for construction in Turtle Creek Park.

Figure 6. A picture of the puncheons constructed at Turtle Creek park based on the images and structural techniques provided to the team by Brian Aumann.

The alternative to this would have been the full-length boardwalk which not only would have been far more expensive and time consuming, but it also jeopardizes the health of the wetland habitat and makes the mowing process more difficult for the township employees. In our

meeting with Char and Jim, we reached out to several lumber yards in an attempt to gain a pricing for the amount of lumber we would require for our puncheons. Because of the association with Bucknell University, the lumber is only about $0.90 per foot. In this purchase, we bought 250 ft worth of 12 ft x 1ft x 2 inch pieces of lumber. The 250 feet were separated into 4 sections, one which is 40 feet in length, one which is 80 feet in length, one 60 feet in length, and one last section which is 70 feet in length. With puncheons that are two boards in width, the total of 12 foot boards comes to about 50 pieces. In order to support these, we also needed 6 inch by 6 inch square pieces of wood which were 3 feet long that provided the base of the puncheon. When these are placed at each of the 10 foot sections, we required about 50 of these as well. In the final lumber order, we placed an order for 50 of the 12 foot long boards and 75 of the 6 inch by 6 inch square foot boards. The total on this order came to $2002.73, and we were able to order some extra pieces in case of mistakes with cutting the wood. Community partner Char Gray also suggested that we place a third 6 by 6 by 3 piece of lumber in the middle of the 12 foot boards because the boards were somewhat flimsy when they were walked on. In order to keep these boardwalks together, Brian Aumann suggested the use of deck nails that are hammered in at an angle to assure that the walkway stays together. If there are four of these nails used in each end of the 12 foot boards, we estimated needing between 100-150 nails. We ended up buying around 300 of these nails at Cole's Hardware in Lewisburg, which was a good idea because many of the nails ended up bending when they were hammered into the white oak underneath the 12 foot approximated hemlock pieces. While our team waited for the delivery of the lumber order, we continued our exploration into ways that we can get Bucknell University students involved as volunteers for the construction process. Most volunteers for the project were sourced through Bucknell's Football team and the community "Friends of Turtle Creek" Facebook page. It is important to note that projects of this type should also involve those that it will impact most: members of the surrounding community. While most of our volunteers came from the Bucknell football team, we felt it was important to provide community members to get involved with a project which they would be using for the years to come. Thanks to Char Gray, we were able to source a volunteer from the boy scouts and from several others who responded to her advertisement in the Friends of Turtle Creek Facebook group.

Once the lumber was delivered we were able to successfully carry and build two of the four segments we originally planned to build. This was approximately 108 feet in length and

stretched across the muddiest sections in the North end trails. Because the lumber we ordered was “rough cut” it was longer than we had anticipated in length, with some of the lumber reaching a little more than 14 feet each. This was convenient because it required less pieces of lumber per section and also made it easier to place the “sleeper” 3 foot pieces since the length of the boards was longer. One challenge we had during the construction phase was lifting all of these pieces from the delivery sight to the construction site. Because of the rain, the wood was much heavier than dry wood, making it difficult to carry through the muddy trails. Another challenge we had was leveling the “sleeper” pieces with the gravel in the worst areas. The muddier trails filled with water much faster, causing us to fill the dug out spots with far more gravel than others. In addition, pushing this gravel down the trail to the construction site was challenging because the gravel was equally as heavy as the lumber, and may have been heavier when it was wet after rain storms. The gravel bent some of the plastic wheelbarrows we had and made it almost impossible to push down the hill to the trail. Because of the heavy lifting, extensive digging, and nailing after construction, it was somewhat difficult to obtain volunteers for a long period of time, and our project team became tired after a couple of hours. This ended up limiting the amount of physical labor our team was able to accomplish, but we still set up several boardwalks as an example for future construction, as well as marking out areas that still need puncheons and laying out the wood for some of them.

Figure 7. The Turtle Creek project team worked with Jim Knight, Brian Auman, and Char Gray to obtain measurements of all problem areas that will have puncheon boardwalks.

Invasive Species Findings

The initial idea in evaluating the invasive species in Turtle Creek Park was to analyze the quality of the soil in areas full of invasive species and areas which maintain native species and forestation. In doing this, our team was hoping to present scientific evidence to our community partners to show why prioritizing other revitalization efforts may be equally as important as the boardwalk project. We were hoping that soil sampling would provide answers as to why the soil is not absorbing the water in areas taken over by invasive species and compare this to water absorption capacities of soil without heavy presence of invasives. Originally, the Turtle Creek Project Team was in conversation with Matthew McTammany in an effort to take soil samples. While this was a good idea, Brian Auman discussed another method to display this type of analysis. He suggested that sampling from Turtle Creek Park may not produce obvious differences between the soil with the invasive species and the soil without, so a literature review of these types of experiments may be more appropriate for this project. In demonstrating previous literature with these findings, we hoped to bring to light how important the removal of invasive species is to the ecological survival of Turtle Creek Park.

Findings in Reforestation

The last part of the Turtle Creek revitalization project involved reforestation efforts. While we as a team wanted to find places to plant the trees from the on-site nursery, the other aspects of the project had taken priority over the reforestation efforts. This was because the boardwalk project had proven to be more work than anticipated with the funding, the obtaining of supplies, learning to build the boardwalks, then gaining the assistance of both professors and other students to properly build the boardwalks. While we extensively researched the invasive species issues in Turtle Creek Park, this did not extend to reforestation efforts. If more time allowed following the boardwalk plan and the demonstration of the invasive species impact on Turtle Creek Park, the Turtle Creek Project group hoped to develop ideas that would help with planting the on site trees. While this nursery is successful and has been allowing the trees within it to grow safely, there needs to be a development of ideas to find more trees to plant on the property and decide what to do with the existing nursery space after the trees within it can be placed throughout the deforested area. While our team was not able to highlight this aspect of the project, we did conduct a literature review discussing methods of reforestation. We suggest that using this as background information and following through with Brian Auman's park

restoration plan would be the most effective method to addressing the deforested areas in Turtle Creek Park.

Findings in Community Networking

Throughout the length of the Turtle Creek revitalization project, there has been a large web of community relationships involved in several steps of the process. One of the most relevant findings in this project is that developing a community project and following through with its original outcomes can be more challenging when there are more people involved in the process. With Turtle Creek being a public park and considering it is managed by several organizations, it brought several opinions to the forefront of the project development process. Because all of the opinions of the stakeholders in the process are valid, it can make progress difficult.We had to consider regulations to follow about the environment, consideration to accessibility for all path walkers, but something that surprised us was how we had to do this in a reasonable time so this is not inaccessible for long. It has been important to validate all of the stakeholders in the process and also include their opinions in the development of new plans for the park because they deserve to be involved after their continued efforts to conserve the park.

Future Considerations for the Turtle Creek Project

The Turtle Creek project has been an excellent learning experience for the entire project group. We have developed community networking skills, deepened our understanding of wetland restoration, invasive species, and reforestation, and learned a great deal about boardwalk construction, drainage control, and environmental engineering as a whole. In the future, there are several things our project group would suggest for future upkeep and improvements in the park. Because we only finished two of the original four segments of boardwalks we mapped out, we hope that community volunteers or members of East Buffalo Township will be able to finish the construction.

Because our group had little experience in carpentry and construction, we suggest that it would be individuals who have years of experience or are professionals in the field of construction, woodworking, or boardwalk construction. Since measurements, cutting, and actual implementation time could be cut down significantly. In addition, we encourage that the next phase of the project emphasizes the proper removal of the invasive species throughout the park.

Examples are the Multiflora Rose and the HoneySuckle as these are very prominent where the majority of the public will see. While this will likely have to occur in several stages, starting the removal of invasives would be a great start to increasing the ecological health of Turtle Creek. It would be important to consider the full process specifically. We decided we did not have enough time to complete these phases and when dealing with this, a permanent answer is better than short-term. This is definitely one part of the project that our group wished we had more time to focus on because it is a pressing issue throughout the entirety of the park and needs to be carried out in a very specific manner. We suggest reaching out to Brian Auman as a resource for this project as he was incredibly helpful in our boardwalk construction and he also has extensive knowledge about the invasive species issue throughout the park. Lastly, the tree nursery on site could provide future Turtle Creek Projects with a place to store new trees and plant pre-existing ones; however, in order to plant these, much of the existing invasive species need to be completely removed. The tree planting will help restore soil quality and bring native species back to the park. If our group had time, we would have liked to accomplish all of these, but in order to be done successfully, each topic needs to be extensively researched and completed only once knowing how to do each task with the necessary resources and expertise.

In terms of boardwalk and North end trail maintenance, our group suggests that the hemlock boards are checked annually to assure quality of the boardwalk structures. While the White Oaks are in contact with the mud, they rot at a slower rate and are also in more direct contact with the gravel underneath them which will prevent them from rotting as quickly. These may need to be replaced eventually, but this would likely occur several years later. In a suggestion by Auman, he mentioned that the muddy area surrounding the boardwalks which was worsened by construction could be helped by the spread of a seed mixture. The seed type suggested was a Specialized Wetland Mix for Shaded Areas which contains some compost, peat moss, and kitty litter. This seed would total around $521 which could use some of the funding our project has left from the Degenstein Foundation. The seeding will help re-grass areas which are consistently flooded in this area of the park and also decrease the amount of aggressive flooding and muddiness. Using this seed would also help establish site specific native species and reduce possibilities of invasives in this area.

Figure 8. An image depicting the flooded conditions of one of the regions on the North end of the Turtle Creek, about 0.5 miles from the entrance of the park.

Figure 9. An image depicting an area along the north end of the Turtle Creek Park which is almost completely flooded and about 0.6 miles from the entrance of the park.

Conclusion

The history and current state of Turtle Creek Park in Lewisburg highlight the ongoing efforts to conserve and revitalize this important natural area. Despite facing challenges such as invasive species, water runoff issues, and reforestation; the collaborative efforts of community partners, local government, conservation organizations, and university students demonstrate a commitment to preserving the park's ecological integrity. The purchase of the park by East Buffalo Township along with the support from the Merrill Linn Land and Waterways Conservancy, marks a significant step towards restoration and conservation. Through grants, donations, and volunteer efforts; progress has been made in addressing water drainage problems, removing invasive species, and planning for reforestation. The involvement of university students provides valuable hands-on experience and contributes to the long-term sustainability of Turtle Creek Park. By working closely and continuously with community partners and implementing adaptive management strategies, the park's restoration efforts are poised for success. The implementation of puncheons to address water drainage issues and improve accessibility while minimizing environmental impacts. Additionally, the consideration of trail drainage features offers a sustainable approach to managing surface runoff and preserving the natural integrity of the park. Moving forward, continued collaboration, monitoring, and community engagement will be essential to ensure the park's continued health and enjoyment for future generations. We have also left an overload of materials to continue finishing this project in extended parts of the Northern trail.The extra mulch layers and space between the puncheons should allow for prevention of wood rotting. The next step would be to ask the township to continue the puncheon construction, and also to lay the layers of mulch and woodchips since this requires minimal effort and we already have the materials. Turtle Creek Park serves as a testament to the importance of conservation and the power of collective action in preserving our natural heritage.

Appendix

Important Contacts

Jim Knight

Turtle Creek Community Partner and Project Leader.

ebtjames@ptd.net

Professor Andrew Stuhl

Lives in East Buffalo township and frequents the park.

ats011@bucknell.edu

Professor Rob Jacob

Current GIS educator in the Geology department.

rwj003@bucknell.edu

Professor Ellen Chamberlin

Geomorphologist who specializes in rivers and their interactions with environment.

epc005@bucknell.edu

Brian Auman

Currently heavily involved with the project design of the park and is Turtle Creek Park's trail steward.

brian@bsalandplan.com

Professor Matthew McTammany

Professor of Biology & Environmental Studies and Sciences consulted about soil sampling.

mmctamma@bucknell.edu

Professor Elizabeth Capaldi

Professor of Biology & Animal Behavior

ecapaldi@bucknell.edu

Char Gray
Previous Member of the East Buffalo Township Board and part of the Turtle Creek Project Board.
graychar87@gmail.com

References

"0723-2804-MTDC: Wetland Trail Design and Construction 2007 Edition." Www.fs.usda.gov, 2007, www.fs.usda.gov/t-d/pubs/htmlpubs/htm07232804/page05.htm.

Authority, Iron Ore Heritage Recreation Authority. 2024. Marsh Boardwalk.

Barringer, D. (2019, September 27). *Crow's Nest: Boardwalk upgrade*. Natural Lands. https://natlands.org/crows-nest-boardwalk-upgrade/

Bomar, M. B., & Shortt, A. E. (2012, September). Making It Happen: Identifying and Implementing a Reuse to Wetlands Project. In *WEFTEC 2012*. Water Environment Federation.

Brydon, J., Roa, M. C., Brown, S. J., & Schreier, H. (2006). Integrating wetlands into watershed management: Effectiveness of constructed wetlands to reduce impacts from urban stormwater. In Environmental role of wetlands in headwaters (pp. 143-154). Springer Netherlands.

Cook-Patton, Susan. "Reforesting the U.S.: Here's Where We Can Put All Those Trees." Www.nature.org, 1 Mar. 2023, www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/reforesting-united-states-susan-cook-patton/.

Council, P. I. S. (2006). Commonwealth of Pennsylvania Pennsylvania Invasive Species Council Aquatic Invasive Species Management Plan.

Council, P. I. S. (2014). Rapid Response Plan and Procedures for Responding to Aquatic Invasive Species in Pennsylvania Pennsylvania Invasive Species Council.

De Wet, A. P., Richardson, J., & Olympia, C. (1998). Interactions of land-use history and current ecology in a recovering "urban wildland". Urban Ecosystems, 2, 237-262.

East Buffalo Township Conserves Turtle Creek Park With Help From Merrill Linn Conservancy and Others. (2023, March 23). WeConservePA.

https://weconservepa.org/blog/east-buffalo-township-conserves-turtle-creek-park-with-help-from-merrill-linn-conservancy-and-others/

Every Step We Take, They'll Be Watching Us. (n.d.). Retrieved March 25, 2024, from https://superiorhiking.org/wp-content/uploads/2020/06/SHTA-Spring-2020-Ridgeline-Newsletter-compressed.pdf

Gibon, A., Sheeren, D., Monteil, C., Ladet, S., & Balent, G. (2010). Modelling and simulating change in reforesting mountain landscapes using a social-ecological framework. Landscape Ecology, 25(2), 267–285. https://doi.org/10.1007/s10980-009-9438-5

Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement. 2017.https://www.epa.gov/sites/default/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf

Hanniford, K, and Brian Auman. Turtle Creek Park Park Master Plan January 2024. Jan. 2024.

Helwig, J. (2023, July 21). Park and Recreation Donation Program – East Buffalo Township. Ebtwp.org. https://ebtwp.org/park-and-recreation-donation-program/

"Invasive Plant Fact Sheets." Pennsylvania Department of Conservation & Natural Resources, www.dcnr.pa.gov/Conservation/WildPlants/InvasivePlants/InvasivePlantFactSheets/Pages/default.aspx.

"Invasive Species of Concern for Pennsylvania." Pennsylvania Department of Agriculture,

www.agriculture.pa.gov/Plants_Land_Water/PlantIndustry/GISC/Pages/Invasive-Species-in-Pennsylvania.aspx.

Journey with Nature: Autumn Olive. (2020, July 30). The Nature Conservancy. https://www.nature.org/en-us/about-us/where-we-work/united-states/indiana/stories-in-indiana/autumn-olive/

Landowners, L. G. (1997). WETLAND AND RIPARIAN STEWARDSHIP IN PENNSYLVANIA.

Lishawa, S. C., Lawrence, B. A., Albert, D. A., Larkin, D. J., & Tuchman, N. C. (2019). Invasive species removal increases species and phylogenetic diversity of wetland plant communities. Ecology and Evolution, 9(11). https://doi.org/10.1002/ece3.5188

Moon, K., Blackman, D. A., & Brewer, T. D. (2015). Understanding and integrating knowledge to improve invasive species management. Biological Invasions, 17(9), 2675–2689. https://doi.org/10.1007/s10530-015-0904-5

Multiflora Rose. (2019, April 14). Penn State Extension. https://extension.psu.edu/multiflora-rose

Nave, L. E., DeLyser, K., Butler-Leopold, P. R., Sprague, E., Daley, J., & Swanston, C. W. (2019). Effects of land use and forest management on soil carbon in the ecoregions of Maryland and adjacent eastern United States. Forest Ecology and Management, 448, 34-47.

Newcomer Johnson, T.A., Kaushal, S.S., Mayer, P.M. et al. Effects of stormwater management and stream restoration on watershed nitrogen retention.

Peralta, A. L., Ludmer, S., Matthews, J. W., & Kent, A. D. (2014). Bacterial community response to changes in soil redox potential along a moisture gradient in restored wetlands. *Ecological Engineering, 73*, 246-253.

Shields, R. (2021, May). Boardwalks the Bridges to Nature. In *Canadian Society of Civil Engineering Annual Conference* (pp. 571-581). Singapore: Springer Nature Sing

Soil Testing for Ohio Lawns, Landscapes, Fruit Crops, and Vegetable Gardens. (n.d.). Ohioline.osu.edu. Retrieved March 1, 2024, from https://ohioline.osu.edu/factsheet/hyg-1132#:~:text=A%20standard%20soil%20test%20will

Orr, C. H., Stanley, E. H., Wilson, K. A., & Finlay, J. C. (2007). EFFECTS OF RESTORATION AND REFLOODING ON SOIL DENITRIFICATION IN A LEVEED MIDWESTERN FLOODPLAIN. *Ecological Applications*, *17*(8), 2365–2376. https://doi.org/10.1890/06-2113.1

Preece, N. D., van Oosterzee, P., & Lawes, M. J. (2023). Reforestation success can be enhanced by improving tree planting methods. Journal of Environmental Management, 336, 117645. https://doi.org/10.1016/j.jenvman.2023.117645

Reichard, S., Liu, H., & Husby, C. (2012). Is managed relocation of rare plants another pathway for biological invasions?. Plant reintroduced

Sherrill, C. W., Fuhlendorf, S. D., Goodman, L. E., Elmore, R. D., & Hamilton, R. G. (2022). Managing an invasive species while simultaneously conserving native plant diversity. Rangeland Ecology & Management, 80, 87-95.

The Invasive Japanese Honeysuckle. (n.d.). Penn State Extension. https://extension.psu.edu/the-invasive-japanese-honeysuckle

Thompson, J., Pelc, C. E., Brogan, W. R., & Jordan, T. E. (2018). The multiscale effects of stream restoration on water quality. Ecological Engineering, 124, 7–18. https://doi.org/10.1016/j.ecoleng.2018.09.016

“Trail Construction and Maintenance Notebook, 0023-2839-MTDC, Trails in Wet Areas.” Www.fs.usda.gov, www.fs.usda.gov/eng/pubs/htmlpubs/htm00232839/page08l.htm. Accessed 22 Feb. 2024.

“Trail Drainage Features: Development and Testing of an Assessment Tool (U.S. National Park Service).” Www.nps.gov,

“Turtle Creek: A Partnership to Improve Impaired Streams in Union County, PA.” Gis.dep.pa.gov, gis.dep.pa.gov/TurtleCreek/index.html. Accessed 14 Feb. 2024.

Unger, I. M., Kennedy, A. C., & Muzika, R.-M. (2009). Flooding effects on soil microbial communities. *Applied Soil Ecology*, *42*(1), 1–8. https://doi.org/10.1016/j.apsoil.2009.01.007

Unger, I. M., Kremer, R. J., Veum, K. S., & Goyne, K. W. (2021). Immediate and long-term effects of invasive plant species on soil characteristics. *Soil Ecology Letters*. https://doi.org/10.1007/s42832-021-0104-4

Veldkamp, E., Schmidt, M., Powers, J. S., & Corre, M. D. (2020). Deforestation and reforestation impacts on soils in the tropics. Nature Reviews Earth & Environment, 1(11), 590-605.

Verdonschot, P. F. M., & Verdonschot, R. C. M. (2022). The role of stream restoration in enhancing ecosystem services. Hydrobiologia. https://doi.org/10.1007/s10750-022-04918-5

Victorian Stormwater Committee. (1999). Urban stormwater: best-practice environmental management guidelines. CSIRO publishing.

www.nps.gov/articles/parkscience33-1_42-49_burroughs_et_al_3854.htm#:~:text=A%20trail%20drainage%20feature%20or. Accessed 13 Feb. 2024.

Yue, Z., & Burley, J. B. (2021). Predictive Models for Reforestation and Agricultural Reclamation: A Clearfield County, Pennsylvania Case Study. In Vegetation Index and Dynamics. IntechOpen.